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LESSONS LEARNED FROM A DUAL-PHASE EXTRACTION FIELD APPLICATION

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ABSTRACT: A field-scale Dual-Phase Extraction (DPE) system was installed and operated at the Pinellas Science, Technology, and Research (STAR) Center, formerly the U.S. Department of Energy (DOE) Pinellas Plant, in Largo, Florida, from August 1997 through September 1999. The goal of applying the DPE system was to enhance the pump-and-treat remediation of volatile organic compounds (VOCs) (primarily vinyl chloride, toluene, trichloroethene, and 1,2-dichloroethene) from a shallow surficial aquifer at the Pinellas STAR Center 4.5 Acre Site. Initial operating data for the DPE system demonstrated an aggressive groundwater recovery rate; however, influent groundwater contaminant concentrations were less than those experienced with the pump-and-treat system. In addition, multiple issues complicated initial operations. Following numerous system and operational changes, the system responded with consistent on-line time and daily operation; although contaminant recovery rates did not increase.

INTRODUCTION

DPE Technology. DPE is a remediation method that uses vacuum to extract groundwater and soil vapor from a recovery well. Some other common terms used for DPE are Multi-Phase Extraction, Two-Phase Extraction, and Vacuum-Enhanced Recovery (EPA, 1999). Typically, an extraction tube (also referred to as a drop tube or stinger tube) is inserted in a sealed recovery well to the desired depth of recovery at or below the water table. A vacuum pump creates negative pressure in the extraction tube and groundwater is lifted up the tube. The water table is then drawn down to the intake of the extraction tube, at which time vadose-zone vapors are drawn into the extraction tube.

DPE has a number of advantages over conventional pump-and-treat systems. One advantage is that it uses both gravity and pressure differential to move groundwater. Another advantage is its ability to move air and water through formations previously inaccessible. Also, DPE uses two carriers (liquid and air) for contaminant recovery (Nyer et al., 1996).

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Some disadvantages of DPE technology are the associated equipment and maintenance costs, potentially lengthy start-up periods, and depth/vacuum lift limitations (EPA, 1999).

Site Description. The former DOE Pinellas Plant, now the Pinellas STAR Center, is owned by the Pinellas County government and occupies approximately 100 acres (40.5 hectares) in Pinellas County, Florida. The Pinellas Plant operated from 1956 to 1994, manufacturing components for nuclear weapons under contract to DOE. The site where the field application took place, the 4.5 Acre Site, was previously a waste resin and solvent disposal area. In 1984, DOE began to identify potential environmental problems at the STAR Center, including the 4.5 Acre Site. A source removal activity in June 1985 at the site removed 303 tons (275 metric tons) of waste, including 83 drums, solidified drum contents, and 5,000 ft^3 (141.5 m^3) of contaminated soil (S&ME, 1987).

An Interim Remedial Action consisting of groundwater extraction and treatment by air stripping began in May 1990. Operation of the pump-and-treat system continued through July 1997 when, because of reduced contaminant recovery rates, a DPE system was installed to enhance recovery. The site contractor at that time, Lockheed Martin Specialty Components, Inc., designed and installed the DPE system. Following start-up of the system in August 1997, DOE transferred responsibility for environmental restoration activities of the STAR Center to the DOE Grand Junction, Colorado, Office and MACTEC Environmental Restoration Services (MACTEC). Roy F. Weston, Inc., is the technical remediation contractor for MACTEC.

Subsurface Conditions. The 4.5 Acre Site consists of a shallow surficial aquifer contaminated with VOCs, including trichloroethene, *cis*-1,2-dichloroethene, toluene, and vinyl chloride. The water table is generally 3 to 5 ft (0.9 to 1.5 m) below ground surface (bgs) (LMSC, 1997). The surficial aquifer ranges in thickness from 24 to 32 ft (7.3-9.8 m) bgs and is composed primarily of fine sand. Hydraulic conductivity is approximately 2.0×10^{-4} cm/s with a variable presence of silt and clay (S&ME, 1987). The Hawthorn Group, composed primarily of clay, underlies the surficial aquifer.

REMEDIATION METHODS

4.5 Acre Site Groundwater Recovery and Treatment System. The Pinellas 4.5 Acre Site pump-and-treat system began operation in May 1990. The pump-and-treat system consisted of seven recovery wells containing pumps that transferred groundwater to an adjacent treatment system. The treatment system consisted of an equalization tank, a pretreatment phase that settled and collected naturally occurring metals (e.g., iron and calcium) that had fouled the air stripper during initial system start-up, and a contaminant treatment phase in which the groundwater was air stripped to remove VOCs. Effluent was transferred to an industrial wastewater facility that adjusted the pH of the water and discharged it to the county sewer system. This pump-and-treat system, with some performance modifications, operated through July 1997.

4.5 Acre Site Dual-Phase Extraction System. The DPE system was proposed as a modification to the pump-and-treat system to provide a more aggressive means of contaminant recovery. A network of 22 DPE wells was installed during May and June 1997. In 11 DPE wells, organic vapors were detected during well installation, or VOCs were reported in well development water. Concentrations were generally higher in the deeper portions of the wells (MACTEC, 1997).

The extraction well system was divided into three legs to improve operational flexibility. The DPE wells were fully screened through the saturated thickness of the surficial aquifer (from approximately 5 ft [1.5 m] bgs to 30–32 ft [9.1–9.8 m] bgs). In each well a vacuum extraction tube was installed to approximately 22 ft (6.7 m) bgs.

On July 11, 1997, the existing pump-and-treat system was shut down and the seven recovery wells were capped. The DPE system was installed adjacent to the existing groundwater treatment system. The three extraction well legs were merged into a manifold that was connected to a large, phase-separation tank in a pit. To supply the needed vacuum, a 60-horsepower (45-kW) liquid-ring vacuum pump was installed at the ground surface and connected to the top of the phase-separation tank in the pit. Vapors recovered by the pump were routed to the blower intake of the existing air-stripper tower. Groundwater from the bottom of the phase-separation tank was used to maintain the minimum 23 gallons per minute (gpm) (87 L/min) flow necessary for the liquid-ring vacuum pump seal. All influent groundwater was eventually transferred to the influent tank of the existing groundwater treatment system. The groundwater treatment system (air stripper and pretreatment phase) processed the water recovered by the DPE system in the same manner as it had with groundwater recovered by the previous seven recovery wells.

By 1999, it appeared that significant modifications would be necessary to maximize the effectiveness of the DPE system. In September 1999, the DPE system was shut down. A new remediation system using biosparging through horizontal wells was installed at the 4.5 Acre Site and became operational in November 1999.

RESULTS AND DISCUSSION

DPE System Operation. The DPE system was started in August 1997 and continued operation through September 1999. During the initial months of operation, multiple problems complicated the daily operations, thwarted attempts to enhance contaminant mass recovery, and resulted in low system on-line time. Following numerous system and operational changes to address these problems, the DPE system responded with relatively high on-line time (>90 percent) and minimal daily operations complications. Some of the problems and responses to those problems are as follows:

- Groundwater recovery rate following start-up exceeded the treatment system capacity of about 40–45 gpm (151–170 L/min) with all 22 extraction wells operating (MACTEC, 1997). This resulted in the DPE system cycling on and off to avoid overloading the treatment system. Eight of the extraction wells were turned off, resulting in an influent flow of 30–35 gpm (114–132 L/min) and cycling reduction.

- In contrast, as recharge from rainfall decreased and adequate influent flow was not available, use of domestic water was necessary to supplement the minimum 23-gpm (87 L/min) seal water supply. In addition, a larger sheave was installed on the vacuum pump in August 1998 that decreased the minimum seal water supply to 17 gpm (64 L/min).
- In June and July 1998, the piping supplying compressed air to the 4.5 Acre Site began to rupture due to internal degradation of the 10-year-old HDPE pipe. Replacement of the pipe prevented system operation during August and September 1998.
- From May through July 1999, fluctuations in the domestic water supply pressure periodically interrupted the domestic water supplement to the vacuum pump. Fluctuations in domestic water pressure ceased after July 1999.

DPE System Performance. During operation of the DPE system, concentrations of total VOCs in the groundwater influent were relatively low in comparison to previous pump-and-treat influent concentrations. From January through July 1997, the pump-and-treat system's average concentration of total VOCs in the influent was 2,170 μg/L per month. From August 1997 through August 1999, the DPE system's average influent concentration was 416 μg/L per month. Continuous operation of the DPE system did not result in increased influent concentrations (Figure 1).

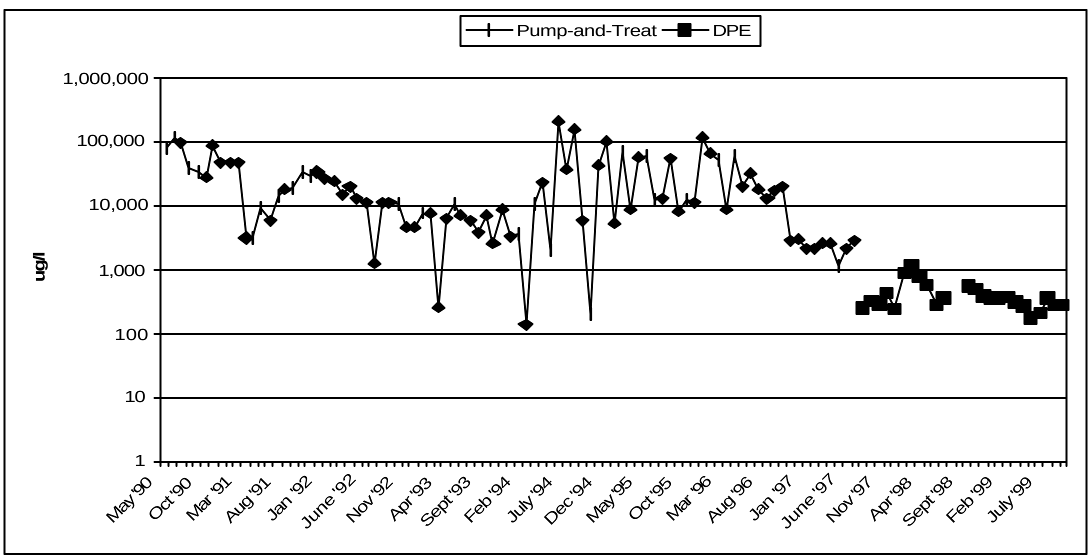

FIGURE 1. 4.5 Acre Site influent VOC concentrations

In contrast, monitoring well M044, which is probably the best groundwater well to monitor effectiveness of cleanup at the site, showed declining total VOC levels (MACTEC, 1999). VOC concentrations in well M044 declined from 1,160 μg/L in May 1997 to 3.1 μg/L in October 1999. Sampling of extraction wells during the DPE system's operational time period showed declining total VOC levels. However, some of the extraction wells with the highest levels of contamination still had concentrations in excess of 10,000 μg/L after two years of DPE system operation. Extraction well E012, for example, had total VOC concentrations in excess of 40,000 μg/L in early 1998; prior to shutting down the DPE system, well E012 had 15,800 μg/L total VOCs.

Concentrations of total VOCs in the influent vapor were also low. Vapors monitored before the vacuum pump during this period ranged from 0 to approximately 100 μg/L (HSW, 1998). Subsequent vapor sampling did not reveal significant increases in contaminant concentrations.

In contrast with influent groundwater contaminant concentrations, the influent groundwater volume increased significantly in comparison to the previous 12–18 months of pump-and-treat operations. From January 1996 through July 1997, the influent volume from the pump-and-treat system averaged 317,835 gallons (1.20×10^6 L) per month. From August 1997 through August 1999, the DPE system's average influent volume was 671,291 gallons (2.54×10^6 L) per month (Figure 2).

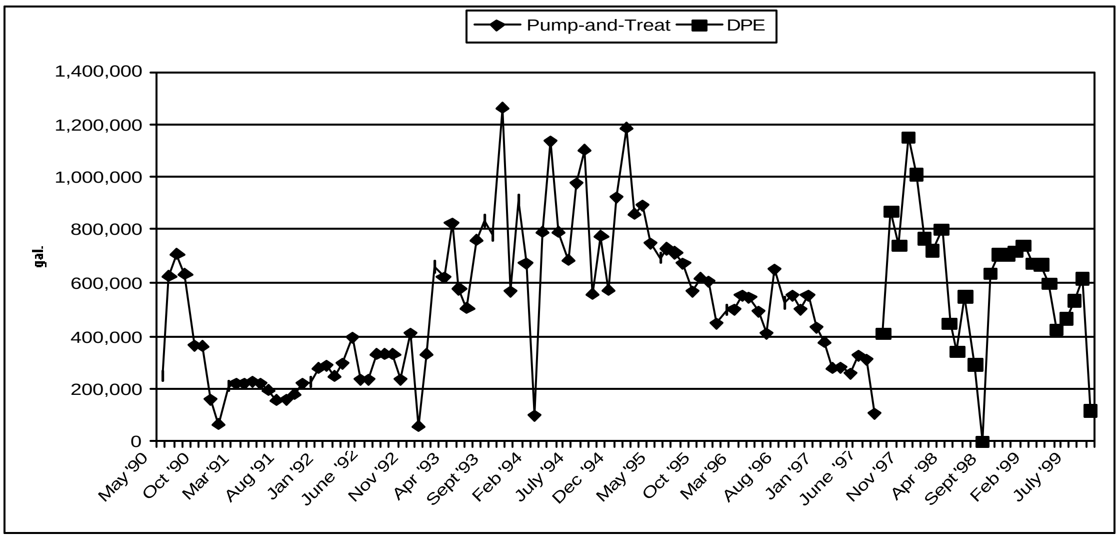

FIGURE 2. 4.5 Acre Site groundwater recovery

VOC mass recovery with the DPE system (both vapor and water phases) was approximately the same or slightly more than with the previous year's pump-and-treat operations. In comparison to historical contaminant mass recoveries, the DPE system was recovering less mass. Continuous DPE system operation through 1998 and 1999 did not show a significant increase in mass recovery over initial operations (Figure 3).

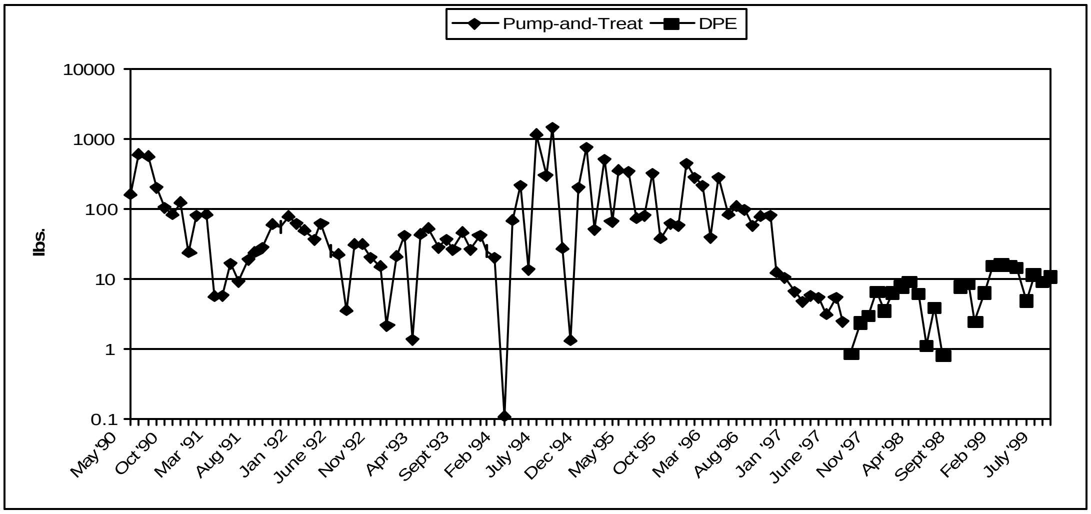

FIGURE 3. 4.5 Acre Site VOC mass recovery

Multiple adjustments were made to the system in an attempt to increase the recovery. The primary focus was to increase the groundwater table drawdown and recover the deeper contamination indicated during installation of the extraction wells. Some of the adjustments and the system's responses are as follows:

- The intakes of the slurp tubes were extended to the bottom of the extraction wells (about 28–31 ft [8.5–9.4 m] bgs). However, the water table was only drawn down to approximately 22 ft bgs (6.7 m) and influent concentrations did not increase.
- Individual legs of the DPE system were isolated by turning off the flow from the other operating legs. The resulting drawdown of the water table was not significantly greater than during previous operations.
- In an attempt to produce airlift pumping, stinger tubes were placed down the slurp tubes of the extraction wells, and a valve on the aboveground end of the stinger tube was opened slightly to bleed air into the slurp tube. The water level in a nearby monitoring well rose approximately one-tenth of a foot, and operation of the stinger tubes was ceased.
- Due to the presence of naturally occurring iron in the site groundwater, precipitation of iron in the extraction well piping and valves caused a significant reduction in groundwater flow and required continual maintenance.
- During initial DPE operations, contaminants were continually detected in the air-stripper tower's effluent. The DPE effluent vapor piping was rerouted up the side of the air-stripper tower and contaminant detections in the effluent ceased.

Costs.

Construction*	$206,000.00
Operations and Maintenance*	$400,000.00
Water Consumption and Disposal	$ 53,727.91
Electrical Power	$ 28,559.40
Total	$688,287.31

*Indicates an estimated cost.

CONCLUSIONS

Lessons Learned. The following are lessons learned during operation of the 4.5 Acre Site DPE system:

- A DPE system should be designed to operate efficiently at the optimum state of recovering both vapor and water. Biasing the system design to move large quantities of water may limit the ability to move large quantities of air.
- Precipitation of naturally occurring iron in the site groundwater can cause a significant reduction in groundwater flow and require continual maintenance.
- A consistent, uninterrupted supply of utility services is essential for a DPE system to reach and maintain the optimum state of recovering both vapor and water.
- The ability to isolate and operate only specific extraction wells attached to a DPE system allows the focus of remediation efforts in specific areas.
- Special attention should be paid to how the vacuum pump seal is maintained. If the pump requires a liquid-ring seal, management of the water supply can greatly affect operation of the DPE system.
- Limitations of a DPE system's lift capability may limit contaminant recovery to shallow depths (<20 ft bgs, 6 m bgs).
- Introducing recovered contaminant vapors into the intake of an air-stripper blower may partition contaminants from the vapor phase to the liquid phase, resulting in detections in the air-stripper effluent discharge.

Summary. The DPE system recovered 177 pounds (80 kg) of VOCs from the 4.5 Acre Site during approximately 23 months of operation. Groundwater recovery totaled approximately 15,726,000 gallons (59.5×10^6 L). During that period, costs for installing and operating the DPE system were approximately $688,000.

DPE system operations at the 4.5 Acre Site demonstrated an aggressive groundwater recovery rate and a decrease in contaminant levels in some wells. However, contaminant recovery was not as aggressive as expected and was at times actually less than the previous pump-and-treat system's recovery. Deeper contamination was not effectively addressed. Consistent operations were hindered at times by utility supply interruptions, iron precipitation, and seal water supply demands. Adjustments and alterations to the DPE system to correct these issues did not produce favorable results. Future applications of DPE systems at other remediation sites should include careful consideration of the lessons learned from this application.

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